

# REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-99-  
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Public reporting burden for this collection of information is estimated to average 1 hour per response for gathering and maintaining the data needed, and completing and reviewing the collection of information, including suggestions for reducing this burden. To Washington Headquarters, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 26, 1999	September - October 1999

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
RESEARCH HIGHLIGHTS	IN HOUSE

6. AUTHOR(S)	Dr Walter Kozumbo      Ms Jean Schaefer
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
AFOSR/NI 801 N. Randolph Street., Room 732 Arlington, VA 22203	

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSORING / MONITORING AGENCY REPORT NUMBER
AFOSR/NI 801 N. Randolph Street., Room 732 Arlington, VA 22203	

11. SUPPLEMENTARY NOTES
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12a. DISTRIBUTION / AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release; Distribution unlimited	

13. ABSTRACT (Maximum 200 words)
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Two stories were included. Development of the lasers and the success of the Airborne Laser Program.
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19991215 068

14. SUBJECT TERMS	15. NUMBER OF PAGES		
Lasers, Program	4		
16. PRICE CODE			
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified	unclassified	

SEP  
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99

# Research

## HIGHLIGHTS

### AFOSR and the development of the LASER

**Dr. Charles Townes is widely regarded as the father of the laser. His invention of the maser in 1954\* provided the theoretical foundation for developing the laser.**

While those facts are generally known, what isn't as well known is that AFOSR helped fund the early works of Dr. Townes, including the development of the maser.

\*He conceived the idea in 1951, the first one operated in 1954.

Following World War II, there was increased emphasis on developing radar equipment that used increasingly shorter wavelengths. The Joint Services Electronic Program was established in 1946, with the Air Force joining the program in 1947, to support former wartime radar laboratories, including

those at MIT and Columbia. The challenge was to develop shorter wavelengths to enable better directivity for the aircraft and to use smaller antennae. Dr. Townes worked extensively in designing radar-bombing systems and has a number of patents in related technology.

From this he turned his attention to applying the microwave technique of wartime radar research to spectroscopy which he foresaw as providing a powerful new tool for the study of the structure of atoms and molecules and as a potential new basis for controlling electromagnetic waves.

*story continued on next page...*



Family, friends and colleagues celebrate with Nobel Prize winner Dr. Charles Townes. Joining the celebration is Dr. Howard Schlossberg (second from left), a long-time AFOSR program manager.



AFOSR and the development of the LASER

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In 1951, Dr. Townes conceived the idea of the maser, and a few months later he and his associates began working on a device using ammonia gas as the active medium. In early 1954, the first amplification and generation of electromagnetic waves by stimulated emission were obtained. Dr. Townes and his students coined the word "maser" for this device, which is an acronym for Microwave Amplification by Stimulated Emission of Radiation.

Critics, who didn't appreciate or understand the significance of the development at the time, dubbed the maser as Means of Acquiring Support for Expensive Research. The maser, in addition to paving the way for the development of the laser, enhanced communication. Because of its sensitivity, it is still used today in atomic clocks.

In collaboration with Dr. Art Schawlow, who shared his interest in microwave spectroscopy, Townes began work on a theory that could enable operations at wavelengths a thousand times shorter than the maser. They first published the principles in 1958 in the *Physical Review*. Work continued on the laser, which was later patented by others in 1960.

In 1964, Townes, along with A. Prokhorov and N. Basov of the Lebedev Institute in Moscow, shared the Nobel Prize in Physics for "fundamental work in the field of quantum electronics which has led to the construction of oscillators and amplifiers based on the maser-laser principle." In 1981, Schawlow was awarded the Nobel Prize for physics for his contribution to the development of the laser.

## New Laser Use Standards



Uniformed Services University of Health Sciences professor Maj. Pat Roach and postdoctoral Fellow Tome Johnson conduct research on the effects of laser light on the human eye. Their research, along with the efforts of Dr. Benjamin Rockwell at Brooks AFB, Texas led to a new national standard on laser light exposure.

# Shed Light on Need for Workers' Eye Protection.

**R**esearchers, funded by AFOSR, have developed new standards to protect workers from the potentially blinding effects of laser light.

The standards are being used by the Department of Defense and have recently been adopted as the national standard through the American National Standards Institute. They have also been proposed as the international standard.

"These new standards will impact the safe use of military, industrial and research lasers worldwide," said Maj. Pat Roach, Ph.D., of the Health Sciences and former AFOSR program manager. He, along with Dr. Benjamin Rockwell of Air Force Research Laboratory and his team from Litton-TASC, conducted research on laser light to fill a gap in safety standards.

These researchers headed up a cross-disciplinary team of investigators consisting of physicists and biologists from universities such as Massachusetts Institute of Technology, Harvard and Duke, as well as from the Air Force Research Laboratory. Prior to this research, there were no safety standards for ultrashort flashes of laser light, despite increasing use of laser technology in both the civilian and military sectors.

"The Department of Defense's use of ultrashort flashes of laser light continues to increase, driven by high operation tempos and new

technological demands," said Roach. "The military uses the technology to illuminate and designate targets, then send the laser-guided munitions to the target. Eventually, they will be used in the U.S.'s theater missile defense system."

Additionally, the use of lasers in the treatment of diseases and injuries has grown significantly over the last few years.

Notwithstanding the tremendous potential of lasers, there are still hazards associated with the technology. Ultrashort flashes of laser light to the human eye may result in permanent blindness. These flashes are less than one nanosecond long, or one billionth of a second. Despite the short duration, they carry a powerful punch. A single nanosecond exposure to the human eye will produce 100 tera-watts (one tera-watt equals 1,000 billion watts) of power at the focusing point within the eye. These ultrashort pulses can produce minuscule "fireballs" which can be as hot as the surface of the sun.

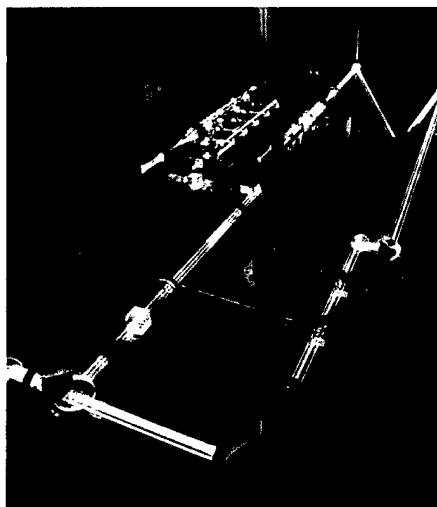
A "direct hit" is not the only danger to the human eye. Indirect or a reflection

off another surface can also harm people.

"Certain lasers are powerful enough to cause blindness when reflected off a carpet or other reflectors like a mirrored surface," said Roach. "Some lasers are so

*"This whole project would not have occurred without AFOSR. AFOSR was the only agency who funded the research."*

— Maj. Pat Roach, Ph.D.



bright that they can cause harm even at far distances."

The new standards detail safety limits when working with ultrashort laser pulses, including the maximum amount of exposure without risking injury. The guidelines also highlight ways to protect the retina and cornea, and include safety precautions for the skin as well. Workers can safely operate research industrial grade lasers, Roach believes, if the right controls safeguards and protections are in place.

AFOSR's role in developing this standard and continuing research on the topic can't be overstated.

"This whole project would not have occurred without AFOSR," said Roach. "AFOSR was the only agency who funded the research."

Research continues on the effects of laser light on the human body. Some of the research initiatives include:

- Research on skin and corneal exposures to lasers used in the Department of Defense, including the Army's hand-held range finder and the Air Force's Airborne Laser weapon system.
- Researchers at the U.S. Air Force Academy, supported by AFOSR, are investigating the molecular effects of laser light on the eye. These studies can be important to the development of pharmacological remedies, the future establishment of a sensitive *in vitro* laser-hazard assessment system, and the identification of sub-threshold tissue alterations that may lead to more serious long-term effects.

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**USUHS contributed to this story.**

## Ongoing AFOSR Support Contributes to the Success of the Airborne Laser (ABL) Program



**A**s with many of today's weapons systems, the Airborne Laser program is a living testament to the importance of basic research to the Air Force.

ABL is a cost-effective airborne high-energy laser system designed to provide a credible deterrent and lethal defensive capability against theater ballistic missiles in the boost phase. The ABL design uses an active tracking system for precision tracking of missile targets. The active tracking system uses an illuminator laser directed from the ABL to the target to provide the signal from which the target position is determined.

AFOSR management of the basic research program has and continues to contribute to the development of the ABL. AFOSR-supported research to enable the ABL began more than three decades ago.

Professor George Pimentel and J.V. Kasper at the University of California, Berkeley, under AFOSR support,

in 1964, demonstrated the first iodine laser. Further critical understanding of the disposition of energy in chemical reactions was gained from AFOSR funded research by Professor Dudley Hershbach of Harvard University and Professor John Polanyi of the University of Toronto, for which they were awarded the Nobel Prize in Chemistry.

Several technologies have enabled the ABL system. One key technology of the ABL is the Chemical Oxygen Iodine Laser. The COIL device converts the energy of chemical reactions into a powerful, infrared laser beam that can travel through the atmosphere and destroy targets at very long distances. An extensive legacy of AFOSR-sponsored basic research to understand, control and optimize the kinetics of molecular interactions led to the invention and development of the COIL. The first COIL device was demonstrated in 1977 at the Air Force Weapons Laboratory at Kirtland AFB, NM.

Continuing AFOSR support over the last two decades enabled COIL technology to mature to the point where high power output with excellent beam quality and long duration run times will meet ABL requirements. The performance requirements of the ABL are established by operational scenarios and support requirements defined by the user, Air Combat Command, and measured target vulnerability characteristics provided by the Air Force lethality and vulnerability community.

Another key technology critical to the ABL is adaptive optics, a control strategy that compensates for atmospheric turbulence effects on the laser beam. Advanced compensation techniques extend the lethal range of the ABL by 50 percent. This technology has been under development at the Air Force Research Laboratory's Directed Energy Directorate for approximately 20 years.

Currently, AFOSR-funded research is being conducted

## Research Highlights

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*Research Highlights* is published every two months by the Air Force Office of Scientific Research. This newsletter provides brief descriptions of AFOSR basic research activities including topics such as research accomplishments, examples of technology transitions and technology transfer, notable peer recognition awards and honors, and other research program achievements. The purpose is to provide Air Force, DoD, government, industry and university communities with brief accounts to illustrate AFOSR support of the Air Force mission. *Research Highlights* is available on-line at:

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within the AFRL in the area of atmospheric characterization. Understanding of the atmosphere, including high altitude cloud ice crystal formation, moisture content, winds, etc, will be used to optimize ABL performance.



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